

WE CLAIM:

1. An inspection system for inspecting an object, the inspection system comprising:
 - a. an external source of penetrating radiation for generating a beam and for
5 irradiating the object, at least intermittently, the beam characterized at each instant of time by an instantaneous energy spectrum and an intensity that may be substantially zero;
 - b. at least one detector configured to detect penetrating radiation including, but not
10 limited to, penetrating radiation backscattered by the object, and to generate a detector signal; and
 - c. a processor configured as a detector signal discriminator to
receive the detector signal,
generate an x-ray image based at least on the detector signal, and
generate an output indicating whether the detector signal is triggered at
15 least in part by an origin other than the penetrating radiation backscattered by the object.
2. A system according to claim 1, wherein the external source of penetrating radiation
substantially emits photons with energies below 250 keV.
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3. A system according to claim 1, wherein the detector signal discriminator generates an
output based on at least one of source- and detected-signal timing and induced spectral content in
the detector signal.
- 25 4. A system according to claim 3, wherein the external source generates a beam that
irradiates the object intermittently and has an intensity that is intermittently and substantially
zero, and wherein the processor generates an output based on source- and detected-signal timing.
5. A system according to claim 1, wherein the detector signal discriminator generates an
30 output when the origin includes beta rays from the object that cause the emission of x-rays.

6. A system according to claim 1, wherein the detector signal discriminator generates an output when the origin includes gamma rays from the object.

7. A system according to claim 1, wherein the detector signal discriminator generates an output when the origin includes neutrons from the object.

8. A system according to claim 1, wherein the at least one detector includes a segment having selective energy sensitivity.

9. A system according to claim 1, wherein the source of penetrating radiation is temporally gated.

10. A system according to claim 9, wherein the source of penetrating radiation is temporally gated by a chopper wheel.

11. A system according to claim 10, wherein at least one spoke of the chopper wheel is substantially opaque to a specific range of penetrating radiation.

12. A system according to claim 9, wherein the source of penetrating radiation is temporally gated electronically.

13. A system according to claim 1, the system further comprising
a current-integrating circuit configured to receive the detector signal of the at least one detector; and

a pulse-counting circuit configured to receive the detector signal of the at least one detector, and to operate during a period when the instantaneous energy intensity is substantially zero intermittently.

14. A system according to claim 1, wherein the at least one detector comprises two serial scintillators.

15. A system according to claim 14, wherein an x-ray absorbing wall is interposed between the two serial scintillators.

16. A system according to claim 14, wherein one of the scintillators contains a heavy fluorescing material.

17. A system according to claim 16, wherein the heavy fluorescing material includes at least one of bismuth, gold, and lead.

18. A system according to claim 1, wherein the at least one detector includes a front scintillator and a back scintillator arranged in series, the detected penetrating radiation traversing the front scintillator before impinging upon the back scintillator, wherein the front scintillator is more sensitive to the detected penetrating radiation below a given threshold than the back scintillator and the back scintillator is more sensitive to the detected penetrating radiation above the given threshold than the front scintillator.

19. A system according to claim 18, wherein the front detector is more sensitive to x-rays with energy below 100 keV and the back detector is more sensitive to x-rays with energy above 100 keV.

20. A system according to claim 18 further comprising a converter configured to convert energy of the detected penetrating radiation before the detected penetrating radiation is detected by the back detector.

21. A system according to claim 20, wherein the converter is placed adjacent to a side of the back detector that is opposite a side facing the front detector.

22. A system according to claim 1, wherein the instantaneous energy spectrum of the source is capable of exciting characteristic emission lines of fissile elements.

23. A system according to claim 22, wherein the source is capable of exciting characteristic emission lines of uranium.

24. A system according to claim 22, wherein the source is capable of exciting characteristic emission lines of plutonium.

25. A system according to claim 1, wherein the beam of penetrating radiation is a pencil beam.

26. A system according to claim 1 further comprising:

a first scintillator capable of detecting neutrons and being less sensitive to gamma-rays and x-rays than neutrons; and

a second scintillator capable of detecting photons and being less sensitive to neutrons than gamma rays and x-rays;

wherein the detection signal discriminator generates an output when the origin includes neutrons from the object.

27. A system according to claim 26, wherein the first scintillator is a large area gadox screen.

28. A system according to claim 26, wherein the first scintillator is a ^6Li -based scintillation screen.

29. A system according to claim 26, wherein the first scintillator is a high pressure ^3He proportional counter.

30. A system according to claim 26, wherein the second scintillator is essentially transparent to neutrons and the first and second scintillators are serially arranged such that detected neutrons traverse the second scintillator before impinging on the first scintillator.

31. A system according to claim 26, wherein the second scintillator is a moderator of fast neutrons and captures high energy photons, and wherein the first and second scintillators are

serially arranged such that detected neutrons traverse the second scintillator before impinging on the first scintillator.

32. A system according to claim 31, wherein the second scintillator is configured to capture photons with energies higher than 100 keV.

33. A system according to claim 32, wherein the second scintillator is one of a plastic scintillator and a liquid scintillator.

34. A system according to claim 33, wherein the second scintillator has a thickness in the range of approximately 2 cm. to 10 cm.

35. A system according to claim 33, wherein the second scintillator is segmented.

36. A directional detector of radioactive emissions comprising:
a scintillator for capturing an emission from a radioactive source, the scintillator having a detection dimension with a total thickness greater than the mean free path of the emission in the scintillator; and

an optical detector configured to detect photons emitted from the scintillator in a direction of the detection dimension.

37. A directional detector according to claim 36, wherein the scintillator emits photons after capturing neutrons, the neutron mean free path in the scintillator being shorter than the photons mean free path in the scintillator.

38. A directional detector according to claim 36 further comprising:
shielding configured to prevent the scintillator from capturing neutrons directed from a direction other than the direction of detection dimension.

39. A directional detector according to claim 38, wherein the shielding substantially includes at least one of ${}^6\text{Li}$, ${}^{10}\text{B}$, ${}^{113}\text{Cd}$, and ${}^{157}\text{Gd}$.

40. A directional detector according to claim 36, wherein the scintillator comprises at least two separate pieces separated by the optical detector, the optical detector being substantially neutron transparent.

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41. A directional detector according to claim 36 further comprising another optical detector positioned on an opposite side of the scintillator from the optical detector.

42. A directional detector according to claim 36 further comprising:
a neutron moderator material surrounding at least a portion of the scintillator.

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43. A directional detector according to claim 42, wherein the neutron moderator contains hydrogen.

44. A directional detector according to claim 43, wherein the neutron moderator includes at least one of high density polyethylene and water.

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45. A method for detecting neutrons, the method comprising:
a. providing a scintillator containing high neutron-capture-cross-section atoms for capturing the neutrons and emitting electromagnetic radiation, at least one dimension of the scintillator exceeding the mean free path in the scintillator of a photon of a specified wavelength range; and
b. detecting photons at the specified wavelength range with a photodetector characterized by a position with respect to the scintillator.

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46. A method according to claim 45, further comprising:
c. inferring a direction of a detected neutron with the position of the photodetector.

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47. A method according to claim 45, further including the step of moderating incident fast neutrons for capture by the containing high neutron-capture-cross-section atoms.

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48. A method for detecting concealed fissile material comprising:

a. providing:

- i. a first scintillator screen for absorbing massive fission products and generating visible light;
- ii. a second scintillator screen in a path of photons that have traversed the first scintillator screen;
- iii. a heavy element backing in a path of photons that have traversed the second scintillator screen for generating Auger electrons and concomitant secondary photons;

and

b. detecting visible photons arising in the first and second scintillators.

49. A method for creating an x-ray image of an object and detecting clandestine nuclear material associated with the object, the method comprising:

- a. illuminating the object with penetrating radiation;
- b. detecting emission, including penetrating radiation, emanating from the object;
- c. producing an x-ray image of the object based on the detected emission; and
- d. distinguishing between detected emission due to scattered penetrating radiation with the object and detected emission due to the clandestine nuclear material.

50. A method according to claim 49, wherein distinguishing includes distinguishing detected emission due to fissile material.

51. A method according to claim 49, wherein distinguishing includes distinguishing detected emission due to a dirty bomb.

52. A method according to claim 49, wherein the detected emission includes gamma rays from the clandestine nuclear material.

53. A method according to claim 49, wherein the detected emission includes x-rays generated by beta rays from the clandestine nuclear material.

54. A method according to claim 49, wherein the detected emission includes neutrons from the clandestine nuclear material.

5 55. A method according to claim 54, wherein illuminating the object includes at least one of moving the object relative to a neutron detector and moving the neutron detector relative to the object, the method further comprising correlating a detection signal from the neutron detector with the relative position of the neutron detector and the object to identify the approximate location of a neutron emitter.

10 56. A method according to claim 49 further comprising:
locating the clandestine nuclear material associated with the object using the x-ray image.

15 57. A method according to claim 49 further comprising:
identifying a potential location of the clandestine nuclear material using the x-ray image;
and
redetecting emission emanating from the object after repositioning the object based on the identified potential location.

20 58. A method according to claim 49, wherein illuminating the object includes illuminating the object intermittently, and distinguishing includes distinguishing based on at least the source- and detected-signal timing.

25 59. A method according to claim 49, wherein distinguishing includes distinguishing based on at least a distribution of photon energies of the detected emission.

60. A method according to claim 49, wherein detecting emission includes detecting emission due to x-ray fluorescence induced by interaction of the penetrating radiation with the clandestine nuclear material.

61. A method for creating an x-ray image of an object and detecting clandestine nuclear material associated with the object, the method comprising:

- a. illuminating the object with penetrating radiation;
- b. detecting emission, including penetrating radiation, emanating from the object;
- c. producing an x-ray image of the object based on the detected emission; and
- d. identifying heavy metal shielding of clandestine nuclear material associated with the object based on at least identifying a characteristic emission line of active x-ray fluorescence produced by an interaction between the heavy metal shielding and the penetrating radiation.

62. A method according to claim 61, wherein identifying heavy metal shielding includes identifying the presence of lead or tungsten.

63. A method according to claim 61, wherein the heavy metal shielding is identified at least in part by a distribution of photon energies of the detected emission.